Assessing and improving human movements using sensitivity analysis and digital human simulation

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Introduction

Enhancing the performance of technical postures or movements at work, in sports or in rehabilitation is of great concern for humans, and aims both at improving operational results and at reducing biomechanical demands on the body. Advances in human biomechanics and modeling tools allow to evaluate human performance with more and more details using digital human models [1]. However, the reliability of these force-related biomechanical measurements is questionable because most mappings of motion capture data onto a digital model do not ensure the dynamic consistency of the resulting motion [2]. Then, once an existing movement is evaluated, finding the right modifications to improve the performance is still addressed with extensive trial-and-error processes.

Methods

We propose a framework to easily and reliably assess the performance of a technical movement, and automatically provide recommendations to improve its performance. An optimization-based whole-body controller is used to track motion capture data in operational space while imposing dynamic and biomechanical constraints. Existing movements can thus be evaluated. Our method guarantees the dynamic consistency of the resulting motion (*i.e.* that the motion and force respect the laws of physics), without requiring the ground reaction force (GRF) measurement as an input.
Digital human simulations are then automatically created and run (without motion capture) to estimate the performance when the movement is performed in many alternative ways. Sensitivity indices are thereby computed to quantify the influence of postural parameters on the performance. Critical parameters can thus be identified and tuned, using only little input data. Based on these results, recommendations for posture improvement are provided.

Results

The proposed method was validated on a drilling activity. 5 participants performed 10 trials of a drilling movement while their motion, drilling force and GRF were recorded. The tacking error of the replayed motion was smaller than 3 cm and the 6 components of the GRF computed in simulation closely matched their experimental counterparts (Pearson's correlation coefficient between 0.72 and 0.98).
9 postural parameters were varied to create 11601 different simulations of the drilling movement. The sensitivity analysis identified 3 parameters as crucial for the performance, and determined their optimal values. Compared to the original movement, the optimized movement significantly improved 5 performance indicators out of 6, while 1 was only slightly worsened.

Discussion

The good match between the experimental and replayed motion and GRF confirms the relevance of the dynamic replay method. Moreover, the significant increase in performance of the optimized movement shows the usefulness of the digital human simulation-based sensitivity analysis for quickly and easily identifying ways to improve a technical movement.

References

1. Demircan, E., *et al.* (2009), *Engineering in Medicine and Biology Society* p6534
2. Hicks J., *et al.*, (2015), *Journal of biomechanical engineering* 137(2)